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TITLE

CAPITAL ASSET AMORTIZATION MODEL \(CAAM\)

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DEPARTMENT OF NATIONAL DEFENCE

CANADA

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OPERATIONAL RESEARCH AND ANALYSIS

DIRECTORATE OF AIR OPERATIONAL RESEARCH

PROJECT REPORT

ORA-PR-9510

CAPITAL ASSET AMORTIZATION MODEL (CAAM)

by

R.W. Funk
(Air Command Headquarters)

and

G.L. Christopher
(Directorate of Air Operational Research)

SEPTEMBER 1995

OTTAWA, CANADA

National Defence
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OPERATIONAL RESEARCH AND ANALYSIS

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Roger L. Roy

Recommended By: Roger L. Roy, DAOR

P.R. Anderson

Approved By: P.R. Anderson, DGOR

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OTTAWA, CANADA

SEPTEMBER 1995

ABSTRACT

During the inception of Project Genesis, an initiative to streamline Air Force fighter operations and reduce the cost for the provision of a fighter capability, it was discovered that there did not exist a model to account for the total cost of this Air Force component. Models to account for the recurring expenses of personnel, operations and maintenance are available. However, there are no similar models to account for the capital cost associated with a capability. Life cycle costing models do exist, but they do not dynamically account for the effect of operational parameters on the overall annual capital cost of an Air Force capability.

Operational Research was approached to devise a model which could determine the total amortized cost associated with fighter capability. The model must be able to account for all direct and indirect capital expenditures which support the provision of a Canadian Air Force fighter capability. The model must also be able to reflect the effect of changes to operational procedures on the total capital cost of this capability.

The Capital Asset Amortization Model (CAAM) was developed to satisfy this requirement. The model is a spreadsheet which accepts as input the costs of all capital projects which support the retention of an effective fighter capability. From operational data, CAAM determines the approximate lifetime of the air fleet. For capital projects related specifically to the fighter fleet, the fleet lifetime is used to determine the appropriate amortization period for the projects. For non-airframe-specific projects, an associated technological lifetime is used for amortization calculations.

CAAM provides a summary which identifies the total annual capital cost to provide a fighter capability based on the latest estimates of fleet lifetime. CAAM can be used to establish a baseline cost for fighter capability and measure the effect of changes to infrastructure and operations.

RÉSUMÉ

Au début du projet "Genesis", une initiative pour rationaliser les opérations de combat de l'armée de l'air et réduire le financement des capacités des chasseurs, on a découvert qu'il n'existait pas de modèle pour calculer le coût total de cette composante de l'armée de l'air. Il existe des modèles pour calculer les frais généraux du personnel, des opérations et de l'entretien. Cependant, il y a pas de modèles similaires pour les coûts d'investissement associés à une composante. Des modèles pour calculer les coûts d'utilisation existent, mais ils ne prennent pas en compte l'effet des paramètres opérationnels sur les frais généraux annuels d'une composante de l'armée de l'air.

On a fait appel à la recherche opérationnelle pour concevoir un modèle qui pourrait déterminer le coût total amorti associé aux capacités des chasseurs. Le modèle doit calculer toutes les dépenses capitales directes et indirectes qui supportent le maintien des capacités des chasseurs de l'armée de l'air canadienne. Le modèle doit aussi montrer l'effet des changements aux procédures opérationnelles sur le coût total de cette composante.

Le modèle "Capital Asset Amortization Model (CAAM)" a été développé pour satisfaire cette exigence. Le modèle est un tableau qui accepte comme entrées les coûts de tous les projets capitaux qui soutiennent le maintien efficace des capacités des chasseurs. A partir de données opérationnelles, CAAM détermine le cycle de vie approximatif de la flotte de l'armée de l'air. Pour les projets capitaux associés spécifiquement à la flotte de chasseurs, le cycle de vie de la flotte est employé pour déterminer la période appropriée d'amortissement des projets. Pour les projets qui ne sont pas associés spécifiquement à la flotte, une vie technologique est employée pour les calculs d'amortissement.

CAAM fournit un sommaire qui identifie le coût total annuel des capacités des chasseurs basée sur les derniers estimés de leur cycle de vie. CAAM peut être employé pour établir un coût de base pour les capacités des chasseurs et mesurer l'effet des changements dans l'infrastructure et les opérations.

EXECUTIVE SUMMARY

Project Genesis is a recently-formulated initiative between Associate Deputy Minister (Material) and the Commander of the Air Force to review all processes supporting and providing an air force capability with a view to streamlining operations and reducing annual costs. The initial focus of Project Genesis is on Fighter Force Capability with a goal of reducing total cost by 25 percent.

In order to achieve its goal, Project Genesis must establish a cost baseline for fighter capability against which changes can be evaluated. A Costing Methodology Working Group (CMWG) was formed to address this issue. The CMWG easily established a costing model for annual costs related to personnel, operations, and maintenance (PO&M), which possess a periodic nature and available data. In the case of capital costs, an acceptable costing model, which could account for the effects of changes to procedures and equipment on capital costs, could not be identified. Operational Research was approached to assist in the definition of a capital costing model.

The Capital Asset Amortization Model (CAAM) has been proposed to address this model requirement. CAAM is a spreadsheet model with a generic layout of worksheets designed to account for all possible categories of capital projects and attributes the projects to Air Force capability, fighter capability in this application. CAAM accepts capital projects which support multiple capabilities and permits such projects to be fractionally attributed to specific capabilities. CAAM addresses considerations related to the estimated life expectancy (ELE) of the airframes associated with capital projects and produces a summary worksheet which relates the output of each fiscal year's capital plan to an amortized (annual) capital cost.

CAAM originates from the principle that if a set of operating parameters were held constant into the future, a cycle of renewal would be established. This cycle would form around the replacement schedules of the airframes providing the capability under examination. Although peaks and troughs would occur when considering cash phasing for these cycles, it is possible to attribute a steady-state annual cost to the provision of the capability. When changes are made to the system, their effects can be extrapolated into the future to determine the new steady-state cost related to the revised system. Such

a model can identify the annual capital cost baseline associated with a specific system and identify the financial effect of changes to the system.

At the root level CAAM utilizes general operational parameters (such as fleet size, flying rates, fatigue limits, etc.) to predict an approximate ELE for the current aircraft fleet and for future fleets. Through a separate worksheet for each class of capital project, all specific capital projects are identified. For each capital project a technological lifetime, base-year cost, fractional component supporting the capability, and dependence upon airframe type are specified. Accounting for project technological life and fleet life expectancy, the amortized cost of each capital project is calculated. A summary table in CAAM identifies the total amortized capital cost associated with the procedures and operational parameters specified for the fiscal year under review.

Data on costs and operational characteristics can be collected annually and entered into CAAM to revise and refine the estimates of amortized capital cost. The effects on cost of deviations from earlier predictions can be examined. CAAM could support an annual review of capital cost requirements.

CAAM can support the objective of Project Genesis by relating the effect of proposed changes to the system supporting and providing the Air Force fighter capability to changes in required capital funding for the capability. CAAM, coupled with the PO&M costing model, can derive the total annual cost for the provision of Fighter Force capability.

In addition to identifying the capital cost of fighter capability, CAAM can easily be extended to support reviews of the entire Air Force capital program and potentially, the capital planning of the entire Defence Services Program. The generic nature of the CAAM methodology permits the model to be applied to any capital program related to a capability dependent upon major equipments with predictable service lifetimes.

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ABBREVIATIONS / GLOSSARY

ADM(Mat)	Associate Deputy Minister (Materiel)
AIRCOM	Air Command
ATF	Advanced Tactical Fighter
CAAM	Capital Asset Amortization Model
CC3	Capability Component Three (Air Command less NORAD)
CEP	Capital Equipment Program
CMWG	Costing Methodology Working Group
DDAS	Director Defence Analysis and Support
DDC	Director Defence Services Program Coordination
DDPG	Defence Development Plan and Guidance
DGAD	Director General Aerospace Doctrine
DGFD	Director General Force Development
DRDA	Director Research and Development Air
DRMC	Defence Resource Management Course
DSFP	Director Strategic Financial Planning
DSP	Defence Services Program
DSPIS	Defence Services Program Information System
ELE	Estimated Life Expectancy
FDSG	Force Development Steering Group
FG	Fighter Group
FIS	Financial Information System
LCC	Life Cycle Costing
O&M	Operations and Maintenance
PEMS	Program Expenditures Management System
PO&M	Personnel Operations And Maintenance
R&D	Research and Development

Capital Asset Amortization Model (CAAM)

I. INTRODUCTION

BACKGROUND

1. The decline of the Soviet threat and government priorities have resulted in dramatic shifts in Departmental funding over the past eight years. As illustrated in Figure 1, the magnitude of the changes to the Department of National Defence (DND) Reference Levels[1] since the 1987 White Paper is quite significant. These changes require DND to rethink all its activities and capabilities.

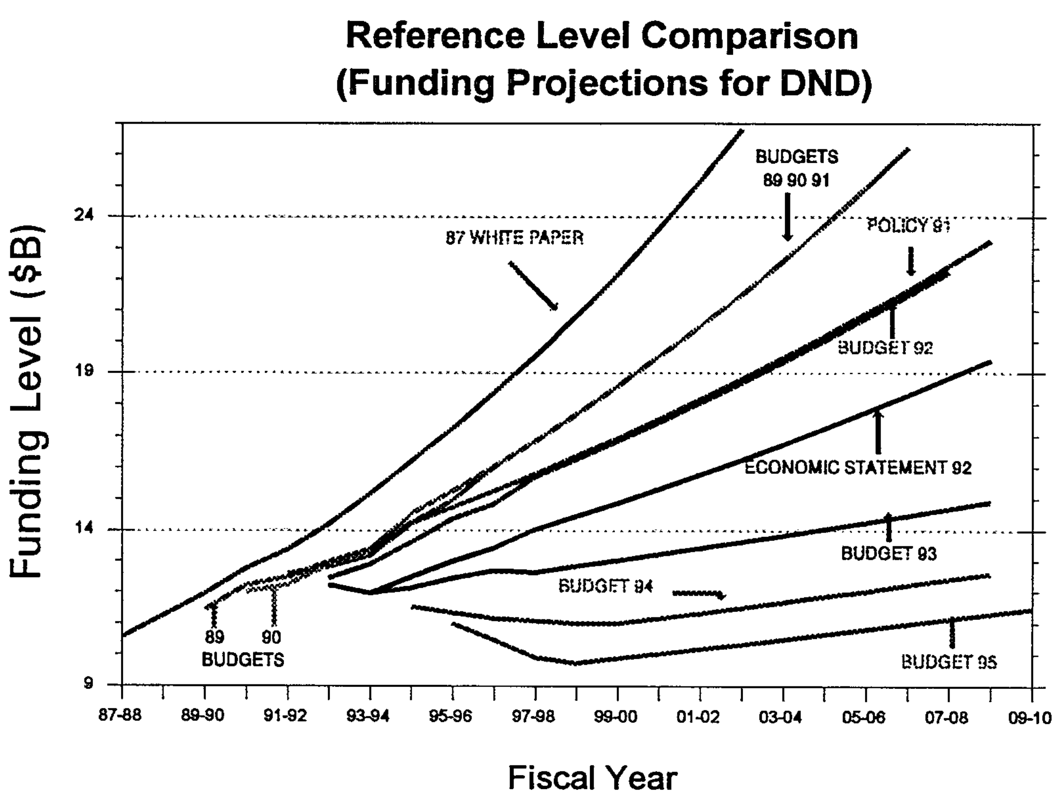

Figure 1 - DSP Funding Projections Over Time

Source: DSFP Slide 054E.PRS 1 Mar 95

1. This report assumes the reader is familiar with Defence Services Program (DSP) issues and terminology defined in the Defence Program Management System (DPMS) [1]. A " brief and informal walk through the DPMS jungle" in simple language is also available from Director DSP Coordination (DDC) [2].

2. A major component of the December 1994 Defence Review was the announcement that the cost of fighter capabilities would be reduced by at least 25 percent. The Commander of the Air Force and Senior ADM (Mat) responded with Project Genesis [3]. The broad mandate of Project Genesis is "to examine the processes behind every facet of Air Force operations with an initial focus on Canada's Fighter Force Capability. The goal of Project Genesis is to produce a blueprint for an Air Force framework within which individual initiatives to increase effectiveness and reduce costs can take place." The Operational Research component of Project Genesis is a cooperative project that involves the Air Command Headquarters Operational Research (Op Rsch) Division, the Fighter Group (FG) Headquarters Director of Operational Research (DOR) and the Director Air Operational Research (DAOR) at NDHQ.

3. During the initial discussions of Project Genesis, it was decided that one of the first tasks that must be undertaken is to establish the current cost of operating Canada's fighter force. The need to properly define the initial baseline cost of fighter capability led the Project Genesis team to convene a Costing Methodology Working Group (CMWG). Its initial focus was on ensuring the costs in the baseline for Fiscal Year 1993-1994 (FY 93/94) are both comprehensive and authoritative. This baseline costing is to be used as the standard for Project Genesis to measure the progress towards the Defence Review goal of "reducing the cost of fighter force capability by 25%".

PERSONNEL, OPERATIONS AND MAINTENANCE (PO&M) COSTING MODEL

4. The first meeting of the CMWG was able to easily deal with the PO&M costing model because that component of the problem has an existing well-developed methodology. In fact, Project Genesis considerations led to the development of a sophisticated PO&M costing model designed for this specific costing application. It pulls together a large body of evidence from all aspects of PO&M through a very extensive set of data files drawn from the Financial Information System (FIS) and the Defence Services Program Information System (DSPIS). The PO&M costing model is so interwoven that it requires a detailed "roadmap" for users to navigate through the myriad of linkages between the various components. Its major advantage is that all the costs are stated as annual expenditures that can easily be updated from a few authoritative sources.

5. Yet, despite all this effort at articulating PO&M costs, the model was only able to link a small percentage of the overall costs to expenditure data. This means that the model is forced to rely on a large number of standard costs. These will have to be constantly scrutinized as to their validity and reliability because the Project Genesis initiatives will force significant changes to work methods and operating assumptions over the next few years. For this reason a detailed data dictionary of all cost considerations is recommended to identify and gather together the data assumptions into a single coherent picture.

PORTRAYAL OF CAPITAL

6. The Defence Services Program (DSP) development framework, as currently configured, is based on a time period of fifteen years. Once the PO&M aspects have been catered for, the remainder of the resources is allocated to the Capital Equipment Program (CEP) illustrated in Figure 2 and split into two components:

a. Approved Capital is the wedge on the left that slopes downward as the projects are completed over the next six years. A small slice representing the ammunition and miscellaneous requirements, labeled as "OTHER" in the Figure, continues through the full period; and

b. Capital Plan is the much larger area in the centre and right of the figure that represents the aggregated plans culled from a large list of potential projects. These projects are limited to those technology modernization and replacement projects that have been approved by Force Development Steering Group (FDSG) based on the Defence Development Plan and Guidance (DDPG) priorities.

7. The effect of the above situation is that CEPs tend to become overprogrammed (more demand than funding) in the near term ("inner" years). The DND resource managers compensate for this by deliberately underprogramming[2] the "outer" years in order to stay within the overall funding limitations. This is just as well because the fifteen

2. Underprogramming represents the amount by which funding exceeds the demand for the period under consideration. Overprogramming is where demand exceeds funding.

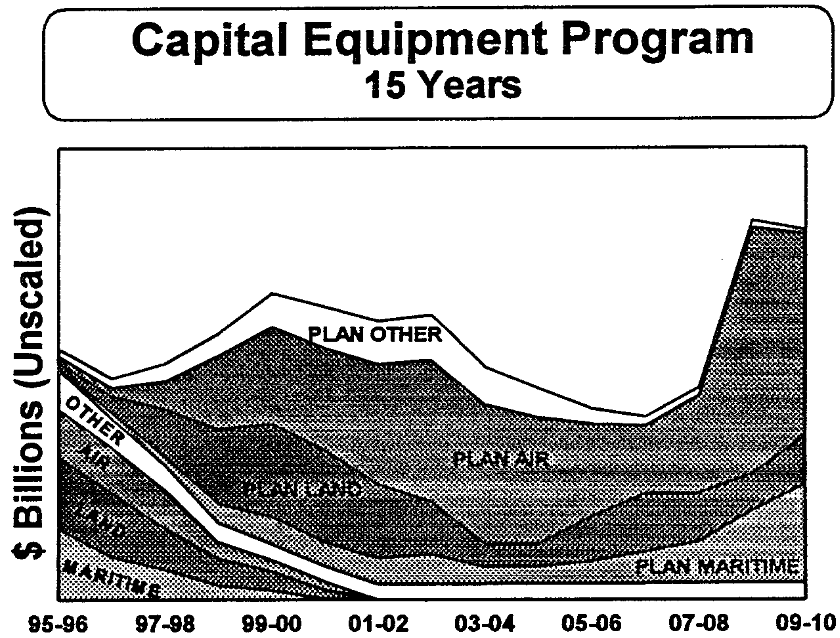

Figure 2 - DSP 15 Year Capital Equipment Plan
Source: DSFP Slide 272E.PRS 28 Mar 95

year planning period makes it difficult to articulate the full set of requirements because a distant project often depends heavily on the outcome of a number of earlier projects. The situation is further convoluted by the experience that policy rarely remains constant throughout the timeframe due to the evolving nature of the threat to national security. In addition, government priorities are firmly anchored within the federal government's Program Expenditure Management System (PEMS) period of the next five years and tend to be limited to the electoral mandate.

8. Another major difficulty is that all CEP projects have a life cycle that does not easily conform to the costing horizon boundaries. The limited funding causes those projects that cannot be accommodated within the period to be "pushed right " beyond the planning horizon. This becomes a two-way street in cases of gamesmanship where the horizon boundary is used to conceal a project. Hiding a project's costs is a false economy in that all requirements are driven by Estimated Life Expectancy (ELE) considerations involving the eventual replacement of every piece of equipment, whether

or not its cash phasing has been portrayed within the planning horizon or "hidden" to the right. Figure 2 provides a perfect example of what happens when a large hidden demand is forced into the period. In this case it is the CF188 replacement project that creates the large demand on the right side of the figure. Its inclusion will require cancellation of other projects or "pushing them beyond the horizon" in order to keep the CEP within the funding allocation.

9. One natural advantage about the CEP is that it involves monitoring far fewer projects than PO&M initiatives. This is offset by the speculative nature of the CEP due to the multiple views of long term priorities for the limited DSP funding. To put this into perspective, it is useful to trace what happens to Air Force's projects. Air Command submits a plan through Director General Aerospace Development (DGAD) as Capability Component 3 (CC3) requirements based on the DDPG. The FDSG controls access to the CEP by arbitrating between the various CCs' competing objectives plus NDHQ central considerations. This necessitates modifying the cash phasing so the project can fit underneath the capital equipment allocation with other projects already there. The demand is "shoehorned" into the best available cash phasing; which at some point starts to increase overall costs and might also cause a temporary reduction in operational capability. When the Command requirement becomes mixed with projects from the other CCs the project cash phasing eventually changes to such an extent that it bears only passing resemblance to that proposed at the start of the process.

10. There have been a number of previous attempts to grapple with the issue of capability costs. One of the most detailed studies resulted in a one time assessment of "capital residuum" that measures the life of the capital equipment as a ratio of remaining value to replacement cost [4, 5, and 6]. The ideal ratio of one half implies that on average the broad mix of equipment is halfway through its lifespan. The reality is that the residuum has been significantly less than one half for a number of years and continues to decrease with each passing year. Unfortunately, the residuum calculation was a one time calculation and is only valid when reduced to a single measure. In order to be useful the metric must be capable of being replicated at will within a systematic framework.

11. The fundamental problem with the current CEP allocation process is that it concentrates on project specifics, including speculative interactions of cash phasings, long before the policy environment is clear enough to substantiate any specific

procurement activity. What is missing is a reasoned assessment of the full extent of capital costs for a given capability before identifying specific project content or phasing.

AIM

12. This report proposes a capital costing methodology that captures and portrays the fighter force capability total capital costs in a manner that Project Genesis can utilize to make an early assessment about how capital costs will be affected by changes in operating assumptions.

SCOPE

13. The methodology and preliminary setup of the Project Genesis capital model are discussed and defended. A set of initial data has been entered in order to ensure that the model works as postulated but no warranty is made about the veracity of the input values.

II. METHODOLOGY

CAPITAL AMORTIZATION PRINCIPLES

14. Since PO&M costs usually involve regular annual rates of expenditure[3], they are easy to portray over any period of time. Capital, on the other hand, occurs as an extremely lumpy demand that must be smoothed out for cost planning. This is process is supported by Life Cycle Costing (LCC), a well-accepted methodology that calculates the complete cost of the system that can then be amortized as an annual amount. LCC helps to convert the yearly PO&M and lumpy capital costs (upgrades and replacements), such as those graphed in Figure 3, into the amortized values listed in the legend.

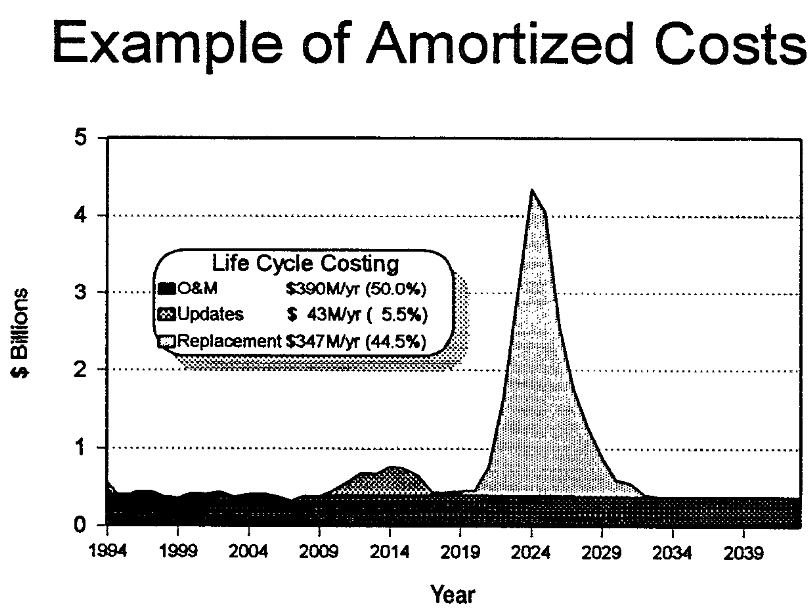

Figure 3 - Example of Amortized Costs

15. The thing often left unrecognized in LCC calculations is that the capital upgrades and replacement projects are two distinct classes of capital linked together in specific ways. The most obvious component is the replacement of the physical platform which

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3. Although relatively stable over short timeframes, PO&M costs generally increase over the lifetime of capital equipment [Ref.10].

involves a major improvement in its technological capability at the same time. What is often omitted is the explicit realization that the technological capability will have to be periodically revitalized while at the same time it is linked to the replacement decision. The interactions between replacement and revitalization projects become that much more intricate when estimated life expectancy (ELE) considerations are also taken into account.

AIRFRAME ESTIMATED LIFE EXPECTANCY

16. The concept of an ELE within the Air Force in the past has focused on the airframes and is composed of two primary factors: attrition and fatigue [7, 8, and 9]. The calculation of the ELE date can be as simple as being an expert's guess as to when an airframe will need replacing or as the result of an extensive simulation of each airframe in the fleet. Figure 4 illustrates how an airframe's ELE behaves.

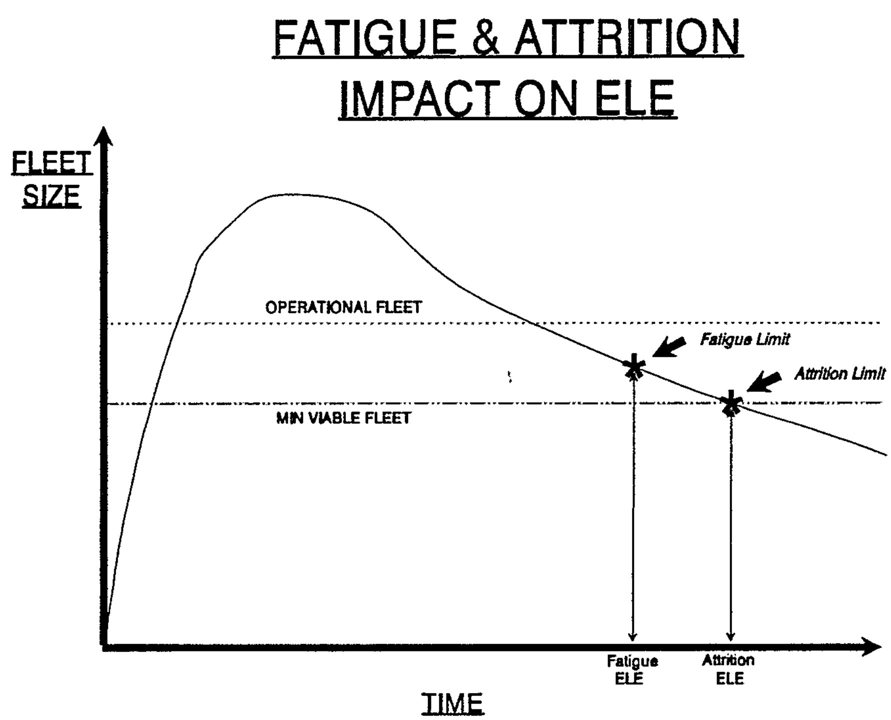

Figure 4 - Estimated Life Expectancy (ELE)

17. The first component of an ELE that occurs is attrition which can happen from the moment the airframe is procured. It then continues as the fleet reaches operational status and eats into the stock of aircraft bought to cater for anticipated attrition. The fleet continues to decrease until either the fatigue life of the remaining fleet is exhausted or the fleet size reaches the minimum number of airframes to continue viable operations. Fatigue can never extend the ELE beyond the natural limit imposed by attrition. Both fatigue and attrition are affected by the rate of operations that 'consume' the aircraft resources. It should be noted that the decision point on replacement airframe procurement (i.e. minimum viable fleet size) is often overlooked when listing factors that affect ELE.

TECHNOLOGICAL ELE

18. There are many projects in the DSP that are designed to ensure that an airframe keeps pace with technology. Each of these technology modernizations has ELE considerations of its own. What makes them different from the airframe ELEs is that the timing and quantity of technology projects depend on how they relate to specific airframes. Some projects, such as UHF radio replacements, can go into any airframe and are therefore independent of any single airframe's ELE. Other projects, such as System Life Extensions (SLEs) that revitalize a specific airframe's avionics, have lifespans that must be explicitly linked to the airframe's ELE. A modelling structure is needed to apportion airframe-related technology projects to appropriate airframes and then take into account their interactions with the airframe's ELE.

19. The annual cost of a technology project ($\$A_t$) that is not linked to any specific airframe simply equals its capital cost ($\$C_t$) spread over the project's technological lifespan (L_t) as:

$$\$A_t = \$C_t / L_t$$

20. Calculating the annual cost of a technological project linked to an airframe ($\$A_{ta}$) requires special consideration because replacing an airframe also revitalizes its technology at the same time. This allows one technology upgrade project to be avoided.

Also, as the airframe approaches the end of its ELE, a decision point may arise as to whether there is sufficient remaining ELE to justify another technological upgrade, or should the technological upgrade be delayed until the airframe is replaced. Hence for each technology project, the fraction of the technology lifetime that is required to justify an upgrade must be set as a threshold. The number of times (N_{ta}) that technology project "t" must be repeated over the lifetime (ELE_a) of airframe "a" becomes a non-negative integer defined by:

$$N_{ta} = truncate\ [\frac{ELE_a}{L_t} + \alpha] - 1$$

where

$$\alpha = truncation\ threshold,\ 0 \leq \alpha \leq 1$$

When **α** is set to one half the technological lifetime (i.e. $\alpha = 0.5$), the value for the number of times the technology project is repeated (N_{ta}) is rounded to the nearest integer value, in the normal fashion.

21. With this in place it is possible to link the capital cost ($\$C_t$) of the technology project to the airframe's ELE using N_{ta}. The amortized cost of the airframe-related technology project is given by:

$$\$A_{ta} = \$C_t * N_{ta} / ELE_a$$

This formula assumes that the cost for each technology upgrade, in base year dollars, and the project technological lifetime remain constant.

22. Linking $\$A_{ta}$ to ELE_a can cause $\$A_{ta}$ to decrease irregularly because the small integer values (typically one or two) of N_{ta} cause the airframe's technological projects to become clustered, usually about the mid-life upgrade points. The decision point at which to add or delete a technological project also can affect $\$A_{ta}$ significantly. At some point the payback period for the project is too small to justify the cost or disruption while at the other extreme the capability gap eventually becomes too great to accept. The result

Examples of Technological Life

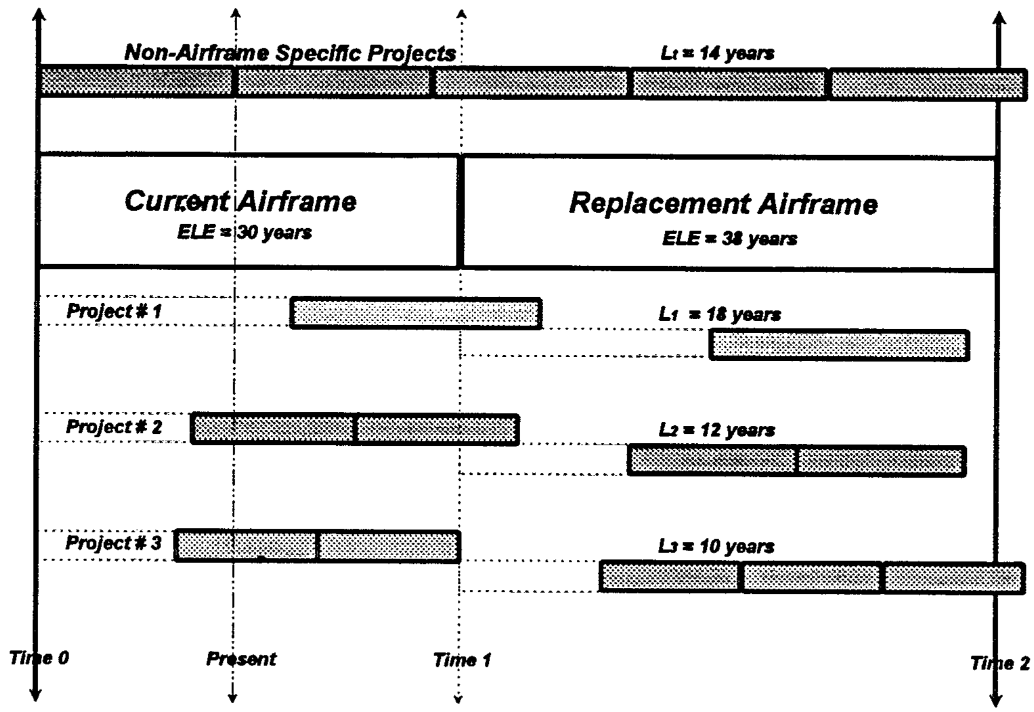

Figure 5 - Examples of Technological Life

of these two factors is that the curve for $\$A_{ta}$ can become very complex; particularly when the number of technological projects and airframes are large or where the assessed value of L_t is subject to significant uncertainty. For the moment the threshold for adding or deleting a technology project has been set at half a technology lifespan ($\alpha = 0.5$) but Project Genesis planners will have to select a more definitive ratio for each project.

23. An example of the concepts described above is covered in Figure 5. In the Figure, the current airframe fleet was acquired at time zero and has an estimated life expectancy of 30 years. The replacement airframe fleet, which is acquired at the end of the current fleet's ELE (Time 1), has an ELE of 38 years. The difference in fleet ELE could be due to changes in airframe technology or methods of operation. The top line shows how non-airframe specific technology projects are independent of airframe procurement cycles. In this example, the non-airframe specific projects occur one immediately after the other, indefinitely in a 14-year cycle. On the other hand, the ELE of the airframe-related

technology projects (listed as #1, #2 and #3) are linked to the procurement of the airframe. As illustrated, the number of times (N_u) the technology project is required changes due to ELE_a, which can vary between the current and replacement airframes.

24. As an example, when the cut off threshold α is 0.5 and the current airframe ELE is 30 years, technology projects with a lifetime of 18 years (Project #1) will be required once. At airframe procurement one technological upgrade is included, so the first project upgrade will occur at one technological project lifetime into the airframe fleet ELE. In the case of Project #1, this occurs at 18 years after Time 0. At this point there is 12 years remaining in the fleet ELE. Twelve years is greater than half the technological lifetime of Project #1, so, one project upgrade is performed. In the case of Project #2, with a lifetime of 12 years, two upgrades would be required. Technology projects with a lifetime of 10 years (Project #3) also require two upgrades. If there were a technology project with a lifetime greater than 20 years ($L_t > 20$ yr), no upgrades would be needed because the remaining airframe ELE after initial technology upgrade at fleet acquisition would be less than 10 years (i.e. less than half the technology project lifetime).

25. If the replacement airframe ELE is 38 years, as in Figure 5, Project #1 would be undertaken once, as with the current fleet. Technology Project #2 would be implemented twice, also as in the case with the current fleet. Project #3 would be utilized three times with the replacement fleet, once more than for the current fleet. After the second upgrade of Project #3, there would be eight years remaining in the replacement fleet ELE. As this is 80 percent of the Project #3 lifetime, a third project upgrade is performed. The case of Project #3 in this example demonstrates the effect increasing ELE can have on the number of project upgrades undertaken. The opposite effect can occur when aircraft ELE is reduced.

SHARED COSTS

26. The PO&M costing model contains an item listed as "Departmental Support to Fighter Operations and AIRCOM" which is an estimate of the overhead from CC4 through CC8 activities that are allocated to each Command. The result is that Project Genesis is being tagged for costs of common CCIS, personnel training and engineering support. To be consistent, the same ratio of CC4 through CC8 capital costs that are attributable to Fighter Operations should also be applied. This value was reached by use of a D Force S matrix that apportions NDHQ CC costs to operational CC's. The original document must be reviewed to assess the reliability and validity of the assigned percentages.

27. In order to be equitable, Project Genesis must determine to what extent the CC4 thru 8 activities assigned to operational commands apply to Fighter Operations. Any difference could be very significant and the direct impact of Fighter Operations resizing might have disproportionate impact on the associated CC4 thru 8 activities. The Project Genesis charter explicitly directs that system improvements from any initiative (eg. Operation (Op) Excelerate and Op Renaissance) that impact on Fighter Operations are to be included. Failure to capture the very significant savings being suggested by Op Excelerate and Op Renaissance would require larger cuts, within an arbitrarily narrowed scope, than is otherwise warranted.

III. MODEL STRUCTURE

SPREADSHEET STRUCTURE

28. The Capital Asset Amortization Model (CAAM) is a spreadsheet model with a generic layout of the worksheets as shown in Figure 6. It works on the principle of an overall worksheet that summarizes the annual output from each fiscal year's capital plan worksheet. In turn, each capital plan captures how each project impacts on technology and airframes. When required, each project can be linked to a detailed ELE worksheet which assesses how the operating assumptions affect fatigue and attrition of the associated airframe fleet.

29. The result is that CAAM can track each year's capital plan on the basis of how the projects' ELE assumptions vary over time. In most cases the detailed ELE worksheets will be limited to a few significant airframe replacement projects (such as the CF188) but the number of worksheets can easily be expanded to cover any combination of projects. The spreadsheet structure also allows each year's work to be accumulated in a standardized summary that allows details of any capital program or ELE calculations to be recast without having to redo previous work.

30. At the lowest level of detail each individual ELE worksheet contains as much information about the ELE as can be used to support the calculation. The input/output area of the worksheet displayed in Figure 7 is typical of the types of issues that should be in a detailed ELE worksheet; in this case it is one year's ELE calculation for the CF188 airframe. The actual CF188 ELE calculations are articulated in detail in References 7, 8, and 9, as well as being captured within the actual spreadsheet model.

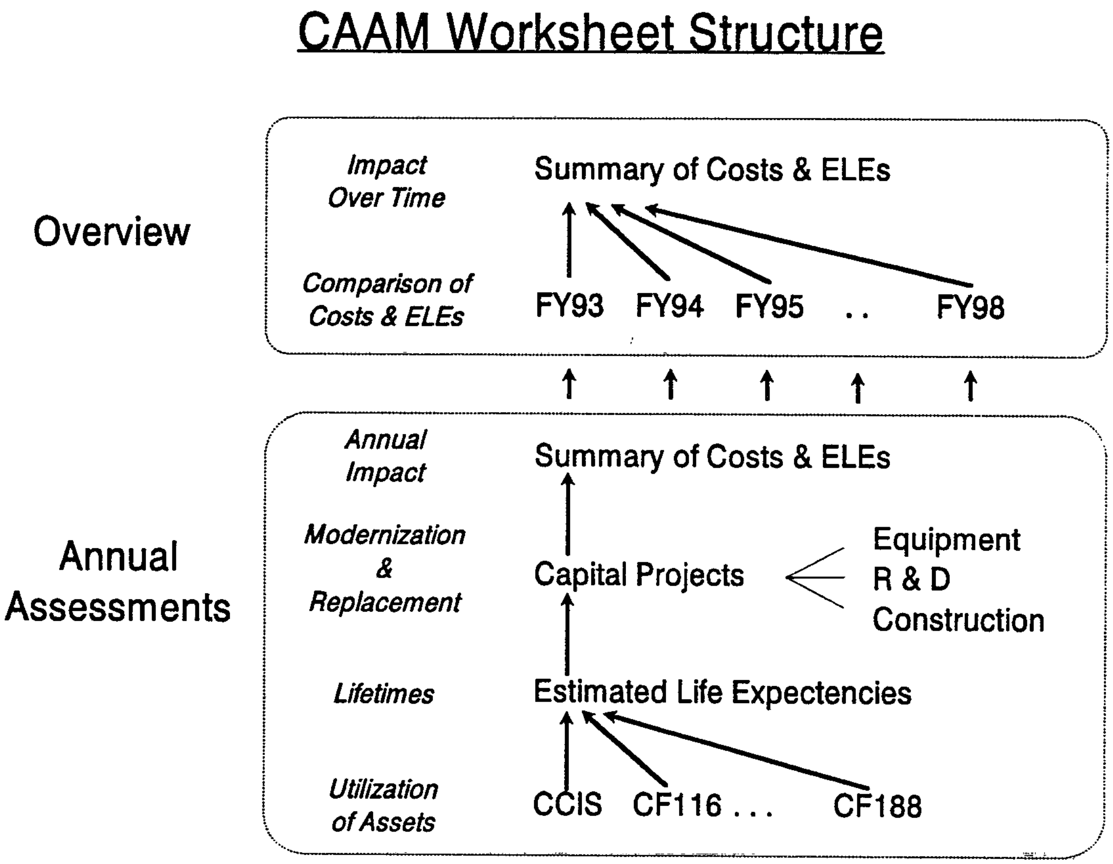

Figure 6 - CAAM Worksheet Structure

31. The ELE worksheet for an airframe (i.e. CF188) incorporates four distinct ELE calculations covered in separate columns as follows:

a. DDPG ELE has the operating assumptions used in the DDPG and should be consistent with the current DSP cash phasing so that replacement airframes are delivered in an orderly manner;

b. Current ELE is the present estimate as to how long the current airframe will remain viable and if the ELE differs significantly from the DDPG estimate, it can be used as the basis for seeking changes to the DDPG. This is the value for the current airframe used by the remainder of the worksheet;

ELE Factors

	ELE Factors	Unit	CF188 DDP	CF188 Current	CF188 Delta	ATF DSP	ATF Plan	ATF Delta
ELE Results	Start Deliveries	Year	1981	1981	-	2003	2022	19
	Fatigue Limit	Year	2006	2024	18	2036	2063	8
	Attrition Limit	Year	2056	2106	50	2044	2075	12
	Reason for ELE		Fatigue	Fatigue	-	Fatigue	Fatigue	-
	ELE Year	Year	2006	2024	18	2036	2063	8
	ELE Duration	# Yrs	25	43	18	33	41	8
Costs	Amortized Cost	$M	-	-	-	$170	$49	($121)
	Project Costs	$M	-	-	-	$5,700	$5,048	($652)
	Fixed Portion of Project	%	-	-	-	25%	-	-
	PO&M	$M	$350	$350	-	$330	$270	($60)
Fleet Size	Total Fleet Involved	# a/c	125	125	-	118	100	(18)
	Early Production A/C (EPA)		11	11	-	-	-	-
	Stored A/C	# a/c	38	38	-	26	38	12
	Size of Operating Fleet	# a/c	87	87	-	99	87	(12)
	Minimum Viable Fleet	# a/c	80	80	-	80	70	(10)
Operations	Total Pilots	# Pilots	108	108	-	140	124	(16)
	Calculated YFR	YFR	26,395	26,395	-	30,180	25,600	(4,580)
Attrition	Rand A		0.0008930	0.0036736	0.0027806	0.0008930	0.0036736	0.0027806
	Rand B		0.76550	0.64287	(0.12263)	0.76550	0.64287	(0.12263)
Fatigue	Equivalent Flying Hours (EFH)	Hrs per A/C	6,000	6,000	-	6,000	6,000	-
	Fatigue Life Expended Index (FLEI)		0.667	1.000	0.333	1.000	1.000	-
	Equivalent Test Hours (ETH)	Hrs per A/C	4,000	6,000	2,000	6,000	6,000	-
	ETH for EPA		2,000	2,000	-	-	-	-
	Cumulative Hours Flown	Total Hrs	270,000	270,000	-	0	0	-
	Avg Fatigue Accumulated per A/C (FAT)		0.330	0.330	-	0.000	0.000	-
	Annual Fatigue Rate		0.111	0.090	(0.021)	0.111	0.090	(0.021)
	Avg EFH Remaining	Hrs per A/C	2,868	6,966	4,098	9,000	11,100	2,100

Figure 7 - CAAM CF188 ELE Worksheet

c. DSP Project ELE is for the replacement airframe ELE assumptions incorporated in the appropriate DPMS documentation; and

d. Planned ELE is based on the latest set of available data and, if the ELE differs significantly from the DPMS document estimate, can be used as the basis for modifying the DSP where appropriate. This is the value for the replacement airframe used by the remainder of the worksheet.

32. Within each ELE column there is an input/output area divided into six main components that cover the following considerations:

a. ELE Results displays the ELE outputs calculated by the worksheet plus the airframe's net amortized costs based on the cost projections provided below;

b. Project Costs inputs the replacement project's capital costs, the approximate percentage of the project that does not vary with the number of aircraft purchased and the PO&M costing model estimate ;

c. Attrition Parameters inputs the Rand Learning curve parameters needed to calculate the average attrition;

d. Fatigue Parameters inputs the appropriate parameters needed to calculate the fatigue limit for the airframe;

e. Operating Assumptions inputs the manning and fleet disposition assumptions that yield the fleet YFR needed for the attrition and fatigue components of the ELE calculations;

f. Fleet Size Characteristics inputs the decision points about the number of airframes operated and the minimum size of fleet needed for viable operations; and

g. Deliveries Schedule inputs the annual deliveries for the airframe during the course of the replacement project.

33. Once the ELEs have been calculated in the detailed worksheets, the pertinent information is made available to the annual CEP with which it is associated. The key consideration is that every capability must have an identified replacement project supported by some sort of costs. This is not needed if the intention is to expend the life of the current asset and then abandon that capability. The FY 93/94 Equipment Plan displayed in Figure 8 illustrates most issues that are likely to occur.

34. Figure 8 is divided into fighter, fighter support and air defence components of the capability based on Project Genesis intentions to track these components. The list of DSP projects within each component is comprised of technological revitalization and airframe replacement projects. The columns associated with each project and a brief description of its significance, if not obvious, follows:

a. DSP Number displays the number assigned to DPMS documentation if the project has any official status in the DSPIS. (Note that the paperwork for a new or dramatically changed requirement takes time to be recognized and tracked in the DSPIS.);

b. DSP Status of Project displays the level of approval the project had as of the end of that fiscal year;

c. Project Name displays the DSP or name most commonly applied to the project;

d. Surrogate displays the airframe(s) by type number with which the project is associated;

e. Status in Future inputs the planners assessment if the project will be needed by the replacement airframe fleet as well as the current one;

f. Associated Airframe inputs the linkage to the appropriate airframe replacement project by airframe number in the component;

g. Technological Life inputs the lifespan in years if it is a revitalization project or outputs the results of the detailed ELE worksheet (if one exists);

h. Amortization Period outputs the airframe ELE if the project is airframe-related or its own technological life if it is non-airframe specific;

i. Number of Times Repeated outputs the number of times an airframe-related project must be repeated over the course of the airframe's ELE;

j. Project Cost in Constant Dollars of that Year inputs cost data in the form that it is available;

k. Escalation Rate inputs the appropriate rate to convert available data to the preferred year for comparison purposes;

l. Project Cost in Constant Dollars of the Preferred Year outputs the cost data in the preferred year for comparison purposes;

m. DGFD Weighting Factor inputs value used by DGFD to allocate a project that exists beyond the scope of one component of fighter capability or is aircraft-related with more than one airframe. Note that in either case the project entry has to be duplicated at the appropriate locations; and

n. Amortized Cost outputs the annualized costs of the project taking account each of the factors described above.

35. The research and development (R&D) projects that are linked to a capability must be articulated in the same way as the equipment plan and are listed in a separate worksheet. The definitive source for Project Genesis R&D inputs is the Director Research and Development Air (DRDA). A major difference from the equipment plan is that a significant component of the R&D effort is spread across a wide variety of technology base activities. It is often very difficult to reliably allocate this effort to specific pieces of equipment. In addition, a major portion of R&D effort is out of phase with the procurement cycle because R&D provides the basis with which to pursue a

procurement project. R&D can be most accurately costed when the research program is most clearly defined with very specific objectives identified. For airframe-related research, this situation usually occurs around the mid-life point of the airframe life cycle, when estimating future equipment requirements and costs is most difficult. Alternatively, during or just after procurement of a replacement airframe, predicting future R&D projects to support the airframe is very difficult and probably inaccurate. The net effect is that the quality of the R&D data is best when the reliability of the equipment data is suspect, and vice versa.

36. The Construction projects are listed in a fairly simple plan with its own worksheet. The definitive source for Project Genesis is the integrated major construction list put together by the Director Decision Analysis and Support (DDAS). Major issues in construction have to do with allocating the utility of a building that is used for multiple purposes (i.e. Hangars) or is common infrastructure. There is also significant difficulty in tracing a large majority of minor construction projects through to capability.

FY 93/94 Equipment Plan

	DSP #	Capital	Name	Surrogate	Future? (0 or 1)	Relates to A/C	Tech Life (Years)	Amortize (Years)	Repeat Times	CFD Jan 92 Capital Plan $92/93	Esc	$93/94	DGFD Factor	Amortized $
Summa			Total							8674003	1	8674003		257075
			Retain							1894725	1	1894725		91370
			Replace							6779278	1	6779278		165705
Fighter			Total							7733234	1	7733234		233486
			Retain							1727955	1	1727955		87016
			Replace							6005279	1	6005279		146470
Retain	A112	A	CF-18	CF-18	0	1	15	41	0	0	1	0	100%	0
	A164	A	CF-18 AAM	CF-18	1		15	15	1		1	0	100%	0
	A166	D	MLS	CF-18	1		15	15	1	145325	1	145325	28%	2713
	A168	A	UHF Replacement	CF-18	1		15	15	1		1	0	29%	0
	A168	D	Adv AA Wpns	CF-18	1		15	15	1	476771	1	476771	100%	31785
	A168	D	CF-18 SLE	CF-18	1	1	15	41	2	866234	1	866234	100%	42255
	A193	D	CRV-7 Update	CF-18	1		15	15	1	7224	1	7224	100%	482
	A197	A	CF-18 Fuel Tanks	CF-18	1	1	15	41	2		1	0	100%	0
	A197	A	CF-18 Pylon Eqpt	CF-18	1	1	15	41	2		1	0	100%	0
	A198	A	CF-18 EW Expenables	CF-18	1		15	15	1		1	0	100%	0
	A211	D	CF-18 RWR Mod	CF-18	1	1	15	41	2	13857	1	13857	100%	676
	A237	C	GPS	CF-18	1		15	15	1	68965	1	68965	28%	1287
	A237	D	NORAD Deploy Sp	CF-18	1	1	15	41	2	29408	1	29408	100%	1435
	A252	D	CF-18 BLOS Comms	CF-18	1	1	15	41	2	30231	1	30231	100%	1475
	A255	A	CF-18 APG65 RUG	CF-18	1	1	15	41	2		1	0	100%	0
	A256	D	CF-18 EWOSC IOC	CF-18	1		15	15	1	20300	1	20300	100%	1353
	A259	D	CF-18 Spat Dis Tnr	CF-18	1		15	15	1	14468	1	14468	100%	965
	A259	E	CF-18 GPWS	CF-18	1		15	15	1	14372	1	14372	100%	958
	A264	E	Adv AS Wpns	CF-18	1		15	15	1	?	1	0	100%	0
	A265	E	CC-150 Strategic AAR	CC-150	1	3	15	25	1	40800	1	40800	100%	1632
	A266	E	CF-18 Stand-off Ammo	CF-18	1		15	15	1		1	0	100%	0
Replace	A252	E	Tactical Fighter		1	1	41	41	1	6005279	1	6005279	100%	146470
	?		Tactical AAR Repl	CK-130	1	2	15	15	1		1	0	50%	0
	?		Strategic AAR Repl	CC-150	1	3	25	25	1		1	0	50%	0

Figure 8a - CAAM FY 93/94 Equipment Program Worksheet

FY 93/94 Equipment Plan

	DSP #	Capital	Name	Surrogate	Future? (0 or 1)	Relates to A/C	Tech Life (Years)	Amortize (Years)	Repeat Times	CFD Jan 92 Capital Plan $92/93	Esc	$93/94	DGFD Factor	Amortized $
Fighter Support			Total							794502	1	794502		17331
			Retain							118623	1	118623		3002
			Replace							675879	1	675879		14329
Retain	A10	A	EST Challenger	CE-144	1	3	15	20	0		1	0	100%	0
	A10	A	EST Challenger	CE-144	1	3	15	20	0		1	0	50%	0
	A14	D	AETE Upgrade		1		15	15	1	81767	1	81767	10%	545
	A16	A	Tacan Replacement		1		15	15	1		1	0	31%	0
	A16	A	Parachutes, ALSE		0		15	15	0		1	0	63%	0
	A20	A	CF-5 Rad Alt	CF-5	1	1	15	25	1		1	0	100%	0
	A21	A	CF-5 AUP	CF-5	1	1	15	25	1		1	0	100%	0
	A22	A	MOB Radars		1		15	15	1		1	0	50%	0
	A24	A	J85 Test Fac - YOD	CF-5	1	1	15	25	1		1	0	100%	0
	A24	A	CT-133 AUP	CT-133	1	1	15	25	1		1	0	50%	0
	A26	D	ACMR/I		1		15	15	1	15406	1	15406	100%	1027
	Axx	E	YBG AG Range		1		15	15	1	21450	1	21450	100%	1430
Replace	A25	E	CSA	116/133		1	25	25	1	675879	1	675879	53%	14329
	?		CH-146	CH146		2	30	30	1		1	0	10%	0
	?		EST Airframe Repl	CC144		3	20	20	1		1	0	100%	0
	?						15	15	1		1	0	100%	0
Air Defenc			Total							146267	1	146267		6258
			Retain							48147	1	48147		1352
			Replace							98120	1	98120		4906
Retain	A13	A	NAADM		1	2	15	25	1		1	0	100%	0
	A13	C	NAADM		1	2	15	25	1	15792	1	15792	100%	632
	A13	E	NAADM		1	2	15	25	1	18000	1	18000	100%	720
	A25	D	TWAS		1	1	15	20	0	14355	1	14355	100%	0
Replace	A25	D	ROCC Repl		1	1	20	20	1	98120	1	98120	100%	4906
	Axx		NNADM Repl	NAADM	1	2	25	25	1		1	0	100%	0

Figure 8b - CAAM FY 93/94 Equipment Program Worksheet

IV. DISCUSSION

COLLABORATIVE DEVELOPMENT

37. To ensure continuity, CAAM is a collaborative effort between AIRCOM HQ and DAOR to implement the worksheet. Director Aerospace Development Coordination (DADC) must be brought into the loop to ensure CAAM is consistent with DGAD's equipment planning assumptions. CAAM has also been explained to D Force S staff and they agree the methodology has applicability to all DSP projects because any project must be able to trace through the timing of its replacement by means of changes to its operating parameters and be associated with a set of approved capabilities.

DATA SOURCE(S)

38. The DSP data was last approved in a capital equipment plan in February 1993. Since then the D Force S staff have not been able to promote a consensus between the CCs. DSPIS has been kept updated from data provided by CCs but no consolidated equipment plan beyond approved projects has been compiled. An authoritative source or sources for DSP data for the affected fiscal years must be found before Project Genesis can track progress as it pertains to capital.

APPLICATION EXAMPLE

39. A sample application of CAAM has been prepared to allow an accurate appreciation of the effectiveness of the model to be acquired. The example deals with capital projects related to Fighter Force capability (CF188). The life expectancy calculations used in this example are those shown in Figure 7. Data pertaining to the equipment-related capital projects is shown in Figure 8, above.

40. While the ELE worksheet, Figure 7, shows life expectancy results for the current fighter aircraft, CF188, these ELE data are not appropriate to use to calculate the total amortized cost of fighter capability for planning purposes. The ELE results for the current aircraft include the effects of many changes in operational procedures and policies that have occurred over the years the fleet was in existence. These results are useful when examining the total amortized cost of the current fleet, however, the proper

planning basis is an ELE estimate based on unchanging operational procedures that would carry forward into the future and would apply over entire fleet life cycles. The ELE estimate for the follow-on fighter aircraft (ATF) to the F-18 meets this requirement and is used as the basis for capability capital costing calculations.

41. From Figure 7, the expected lifetime of the future advanced tactical fighter based on the assumptions used in the DSP is 33 years. However, changes to fleet sizes, flying procedures, yearly flying rates, etc., since the DSP calculation, result in a revised fighter life expectancy of approximately 41 years. These two values will be used in this CAAM application to examine the effects these changes have on the amortized capital cost of the future fleet of fighter aircraft.

42. As stated earlier, the equipment-related capital projects identified in Figure 8 will be used in this CAAM example. Those projects listed in Figure 8 with a "1" in the "future" column will apply to future fighter fleets and will be used in the calculation of the total amortized cost. This condition applies to the majority of the projects listed in Figure 8.

43. Along with equipment capital projects, this application example will utilize data for research and development projects, and construction-related projects which can be associated with the provision of fighter capability. Specific projects of the two classes of capital programs are listed in Figures 9 and 10, respectively. As previously mentioned, these sets of data representing various capital programs were drawn from numerous sources and compiled as accurately as possible. However, the data requires validation, revision, and augmentation. In particular, the data for the R&D and construction capital projects are known to be inaccurate. The data should be viewed as prepared for demonstration purposes only, and not interpreted as a definitive compilation of Fighter Force capital programs.

44. In the capital project worksheets, the latest estimate of the ELE for the replacement fighter fleet is used to determine amortized costs. This estimate is shown in the column "Amortize (Years)" for those capital projects related directly to the airframe. The amortized cost based on the fleet ELE is shown in the last column. Figure 7 uses an ELE estimate of 41 years while Figures 9 and 10 are based a fleet ELE of 33 years. Normally, only one ELE estimate for each airframe type would be used, and this would

be the best current estimate for the replacement fleet. As this CAAM example is comparing the effects of two different ELE estimates, the charts have been mixed. The important information to be gleamed from these Figures is the diversity of the capital projects and their relationship to the airframe type.

45. One will also note, in the Figures, the costs of the capital projects in 92/93 and 93/94 dollars are the same. This is due to the escalation factor being set at a value of 1.0 in all cases. This is stating that there was zero inflation between the two time periods. This is not likely the case, but it was left as such for this sample application of CAAM.

46. Figure 11 contains the summary amortized cost results when an ELE figure of 33 years is used, as specified in the DSP planning calculations. Figure 12 lists the same results when fleet life expectancy is set to 41 years. There is a chart listing the total amortized capital cost of all capital projects, amortized appropriately over the technological lifetime of the project or the ELE of the aircraft to which it is associated. The absolute total cost of all the capital projects is shown in 92/93 and 93/94 dollars. As the escalation factor was set at 1.0 for all the capital projects, the values for the two years are identical in this example. Summary charts are also provided for the various categories of capital projects: equipment, R&D, and construction.

47. From Figure 11, the total amortized cost of all capital projects related to fighter capability is approximately 680.4 million dollars when the fleet ELE is estimated to be 33 years. From Figure 12, the same cost calculated for a fleet ELE of 41 years is 591.2 million dollars. For a 24 percent (8 year) increase in ELE, total amortized capital cost is reduced by approximately 13 percent. This shows the non-linear nature of capital costs with estimated life expectancy of the aircraft fleet. Keep in mind that the numbers used in this demonstration are fictitious and were specified only to illustrate the CAAM process.

48. This simple demonstration shows how operational factors can be linked to the determination of the aircraft fleet ELE, which, in turn, can be linked to the determination of the total amortized capital cost to provide the specific capability.

FY 93/94 R&D Plan

	DSP #	Capital	Name	Surrogate	Future? (0 or 1)	Relates to A/C #	Tech Life (Years)	Amortized (Years)	Times Repeat	CFD Jan 92 Capital Plan $92/93	Esc	$93/94	Factor DGFD	Amortized $
Summary			Total							6779278	1	6779278		201213
			Retain							0	1	0		0
			Replace							6779278	1	6779278		201213
Fighter			Total							6005279	1	6005279		181978
			Retain							0	1	0		0
			Replace							6005279	1	6005279		181978
Retain	A1127	A	CF-18	CF-18	0	1	15	33	0	0	1	0	1	0
	D6xxx				1		15	15	1		1	0	1	0
Replace	A2527	E	Tac Ftr Capability		1	1	33	33	1	6005279	1	6005279	1	181978
	?		Tactical AAR Repl	CK-130	1	2	15	15	1		1	0	0.5	0
	?		Strategic AAR Repl	CC-150	1	3	25	25	1		1	0	0.5	0
	D6xxx						15	15	1		1	0	1	0
Fighter Spt			Total							675879	1	675879		14329
			Retain							0	1	0		0
			Replace							675879	1	675879		14329
Retain	A1056	A	EST Challenger	CE-144	1	3	15	20	0		1	0	1	0
	D6xxx				1		15	15	1		1	0	1	0
Replace	A2533	E	CSA	CF-5/CT-133		1	25	25	1	675879	1	675879	0.53	14329
	?		CH-146	CH146		2	30	30	1		1	0	0.1	0
	?		EST Airframe Repl	CC144		3	20	20	1		1	0	1	0
	?						15	15	1		1	0	1	0
	D6xxx						15	15	1		1	0	1	0

Figure 9a - CAAM FY 93/94 R&D Program Worksheet

FY 93/94 R&D Plan

	DSP #	Capital	Name	Surrogate	Future? (0 or 1)	Relates to A/C #	Tech Life (Years)	Amortized (Years)	Times Repeat	CFD Jan 92 Capital Plan $92/93	Esc	$93/94	Factor DGFD	Amortized $
Air Defence			Total							98120	1	98120		4906
			Retain							0	1	0		0
			Replace							98120	1	98120		4906
Retain	A1399	A	NAADM		1	2	15	25	1		1	0	1	0
	D6xxx				1		15	15	1		1	0	1	0
Replace	A2526	D	ROCC Repl		1	1	20	20	1	98120	1	98120	1	4906
	Axxxx		NNADM Repl	NAADM	1	2	25	25	1		1	0	1	0
	D6xxx				1		15	15	1		1	0	1	0

Figure 9b - CAAM FY 93/94 R&D Program Worksheet

FY 93/94 Constuction Plan

	DSP #	Capital	Name	Surrogate	Future? (0 or 1)	Relates to A/C #	Tech Life (Years)	Amortized (Years)	Times Repeat	CFD Jan 92 Capital Plan $92/93	Esc	$93/94	Factor DGFD	Amortized $
Summary			Total							6942812	1	6942812		203938
			Retain							163534	1	163534		2725
			Replace							6779278	1	6779278		201213
Fighter			Total							6087046	1	6087046		184158
			Retain							81767	1	81767		2180
			Replace							6005279	1	6005279		181978
Retain	A1127	A	CF-18	CF-18	0	1	15	33	0	0	1	0	1	0
	A1478	D	AETE Upgrade		1		15	15	1	81767	1	81767	0.4	2180
Replace	A2527	E	Tac Ftr Capability		1	1	33	33	1	6005279	1	6005279	1	181978
	?		Tactical AAR Repl	CK130	1	2	15	15	1		1	0	0.5	0
	?		Strategic AAR Repl	CC150	1	3	25	25	1		1	0	0.5	0
Fighter Spt			Total							757646	1	757646		14874
			Retain							81767	1	81767		545
			Replace							675879	1	675879		14329
Retain	A1056	A	EST Challenger	CE144	1	3	15	20	0		1	0	1	0
	A1478	D	AETE Upgrade		1		15	15	1	81767	1	81767	0.1	545
Replace	A2533	E	CSA	CF116		1	25	25	1	675879	1	675879	0.53	14329
	?		CH-146	CH146		2	30	30	1		1	0	0.1	0
	?		EST Airframe Repl	CC144		3	20	20	1		1	0	1	0
	?						15	15	1		1	0	1	0

Figure 10a - CAAM FY 93/94 Construction Program Worksheet

FY 93/94 Constuction Plan

	DSP #	Capital	Name	Surrogate	Future? (0 or 1)	Relates to A/C #	Tech Life (Years)	Amortized (Years)	Times Repeat	CFD Jan 92 Capital Plan $92/93	Esc	$93/94	Factor DGFD	Amortized $
Air Defence			Total							98120	1	98120		4906
			Retain							0	1	0		0
			Replace							98120	1	98120		4906
Retain	A1399	A	NAADM		1	2	15	25	1		1	0	1	0
Replace	A2526	D	ROCC Repl		1	1	20	20	1	98120	1	98120	1	4906
	Axxxx		NNADM Repl	NAADM	1	2	25	25	1		1	0	1	0
Infrastructure			Total							81767	1	81767		818
			Retain							81767	1	81767		818
			Replace							0	1	0		0
	A1478	D	AETE Upgrade		1		50	50	1	81767	1	81767	0.5	818

Figure 10b - CAAM FY 93/94 Construction Program Worksheet

Total Capital		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	680,370	617,766	46,534	16,070
	Retain	76,731	71,832	3,547	1,352
	Replace	603,639	545,934	42,987	14,718
$K93/94	Total	22,396,093	19,825,559	2,228,027	342,507
	Retain	2,058,259	1,809,722	200,390	48,147
	Replace	20,337,834	18,015,837	2,027,637	294,360
$K92/93	Total	22,396,093	19,825,559	2,228,027	342,507
	Retain	2,058,259	1,809,722	200,390	48,147
	Replace	20,337,834	18,015,837	2,027,637	294,360

Equipment		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	275,219	251,630	17,331	6,258
	Retain	74,006	69,652	3,002	1,352
	Replace	201,213	181,978	14,329	4,906
$K93/94	Total	8,674,003	7,733,234	794,502	146,267
	Retain	1,894,725	1,727,955	118,623	48,147
	Replace	6,779,278	6,005,279	675,879	98,120
$K92/93	Total	8,674,003	7,733,234	794,502	146,267
	Retain	1,894,725	1,727,955	118,623	48,147
	Replace	6,779,278	6,005,279	675,879	98,120

R & D		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	201,213	181,978	14,329	4,906
	Retain	0	0	0	0
	Replace	201,213	181,978	14,329	4,906
$K93/94	Total	6,779,278	6,005,279	675,879	98,120
	Retain	0	0	0	0
	Replace	6,779,278	6,005,279	675,879	98,120
$K92/93	Total	6,779,278	6,005,279	675,879	98,120
	Retain	0	0	0	0
	Replace	6,779,278	6,005,279	675,879	98,120

Construction		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	203,938	184,158	14,874	4,906
	Retain	2,725	2,180	545	0
	Replace	201,213	181,978	14,329	4,906
$K93/94	Total	6,942,812	6,087,046	757,646	98,120
	Retain	163,534	81,767	81,767	0
	Replace	6,779,278	6,005,279	675,879	98,120
$K92/93	Total	6,942,812	6,087,046	757,646	98,120
	Retain	163,534	81,767	81,767	0
	Replace	6,779,278	6,005,279	675,879	98,120

Figure 11 - Amortized Capital Cost Summary (ELE=33yr)

Total Capital

		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	**Total**	**591,210**	528,606	46,534	16,070
	Retain	94,095	89,196	3,547	1,352
	Replace	497,115	439,410	42,987	14,718
$K93/94	Total	22,396,093	19,825,559	2,228,027	342,507
	Retain	2,058,259	1,809,722	200,390	48,147
	Replace	20,337,834	18,015,837	2,027,637	294,360
$K92/93	Total	22,396,093	19,825,559	2,228,027	342,507
	Retain	2,058,259	1,809,722	200,390	48,147
	Replace	20,337,834	18,015,837	2,027,637	294,360

Equipment

		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	257,075	233,486	17,331	6,258
	Retain	91,370	87,016	3,002	1,352
	Replace	165,705	146,470	14,329	4,906
$K93/94	Total	8,674,003	7,733,234	794,502	146,267
	Retain	1,894,725	1,727,955	118,623	48,147
	Replace	6,779,278	6,005,279	675,879	98,120
$K92/93	Total	8,674,003	7,733,234	794,502	146,267
	Retain	1,894,725	1,727,955	118,623	48,147
	Replace	6,779,278	6,005,279	675,879	98,120

R & D

		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	165,705	146,470	14,329	4,906
	Retain	0	0	0	0
	Replace	165,705	146,470	14,329	4,906
$K93/94	Total	6,779,278	6,005,279	675,879	98,120
	Retain	0	0	0	0
	Replace	6,779,278	6,005,279	675,879	98,120
$K92/93	Total	6,779,278	6,005,279	675,879	98,120
	Retain	0	0	0	0
	Replace	6,779,278	6,005,279	675,879	98,120

Construction

		Total	Fighter	Fighter Spt	Air Defence
Amortized $K	Total	168,430	148,650	14,874	4,906
	Retain	2,725	2,180	545	0
	Replace	165,705	146,470	14,329	4,906
$K93/94	Total	6,942,812	6,087,046	757,646	98,120
	Retain	163,534	81,767	81,767	0
	Replace	6,779,278	6,005,279	675,879	98,120
$K92/93	Total	6,942,812	6,087,046	757,646	98,120
	Retain	163,534	81,767	81,767	0
	Replace	6,779,278	6,005,279	675,879	98,120

Figure 12 - Amortized Capital Cost Summary (ELE=41yr)

DATA UNCERTAINTY

49. All of the data used in the above calculations are based on average values without identified uncertainty bounds. However, the long timeline and multiple sources of judgemental information suggest that a significant amount of uncertainty exists and there is no assurance that the input distributions are normal. Fortunately, a piece of add-in software for Lotus 1-2-3 (or Excel) called "@Risk" exists that can convert the CAAM spreadsheet from a deterministic calculation into a stochastic simulation. This allows the user to define the distribution of data inputs by quantifying those variables that have some type of uncertainty in cells set aside to capture these entries. @Risk uses these inputs to generate a large number of iterations and then calculates the statistics that describe the net impact of the uncertainty expressed in the distributions.

ELE-O&M LINK

50. It is known and accepted (Ref. 4 and 10) that operations and maintenance costs change over the service lifetime of capital equipment. When equipment is first brought into service, O&M costs are at a minimum. However, as the equipment ages O&M costs increase. For some equipment this increase is linear, for others it can be exponential.

51. As O&M costs are not constant over the lifetime of capital equipment, it is important that this effect be accounted for when determining the total amortized cost of a military capability. This report, and the CAAM model, focus on a method to account for the amortized capital cost of fighter force capability and how to link it to operational considerations which affect the life expectancy of the aircraft fleet. The CAAM model successfully connects the capital life cycle costs to aircraft fleet life expectancy in a dynamic manner. A similar approach may be appropriate for PO&M costs.

52. It is beyond the scope of this development effort and this report to discuss in detail how to ensure that varying O&M costs are properly accounted for. It is left to the Project Genesis Costing Methodology Working Group to ensure that this aspect of life cycle costing is suitably addressed.

V. CONCLUSIONS & RECOMMENDATIONS

CONCLUSIONS

53. To fulfill the mandate and achieve the objectives of Project Genesis, a cost baseline for Fighter Force capability must be established. A model(s) must be found or developed which is capable of identifying the total cost baseline for fighter capability. The model must be able to relate operational and support considerations for fighter capability to total cost (both PO&M and capital costs).

54. The determination of costs related to PO&M appears to be accomplished. A dynamic model capable of identifying the capital portion of Fighter Force capability as a function of operational and support parameter/processes does not currently exist. The Capital Asset Amortization Model, CAAM, was defined to meet this requirement by relating sporadic capital project expenditures to annual funding requirements by relating the projects to airframe life expectancy.

55. CAAM is a reasonable and robust methodology that will allow Project Genesis to realistically portray the capital portion of Fighter Force Capability. Operational planners will have to specify all the data inputs used.

56. CAAM as a general methodology can be used to relate capital expenditures to the provision of a specific capability. It is a capability-based cost planning aid. A draft implementation for Fighter Force has been developed. Its general nature allows the model to be extended to the entire DSP capital program, although it is most directly applicable to the entire Air Force capital program.

57. In its current implementation, CAAM operates only on absolute values for parameters. No allowance is made for the possibility and implications of possible uncertainty in the values. Given the speculative nature of the data required for capital projects that will occur sometime in the future and/or depend on the results of projects that have not yet been completed, uncertainty is an issue which should be considered and resolved. The incorporation of @Risk software into CAAM could address this issue of data uncertainty by allowing total capital program cost to be related to

a measure of the likelihood of occurrence. Capital funding requirements would be associated with a probability. With @Risk imbedded into the model, risk analysis could be utilized when approving a capital project or finalizing the capital plan. Otherwise, there is no formal mechanism to assess the risk of a funding shortfall for a CEP that is being evaluated.

RECOMMENDATIONS

58. A meeting of planners should be convened to review the proposed model, CAAM, and the capital and operational planning assumptions that should be used. Authoritative sources of data must be specified and meaningful values assigned. The meeting should also assess the level of detail to which the ELE calculations should be pursued for each technology project and airframe.

59. At the planners meeting, an assignment of responsibility for the provision of the input data to support CAAM should be made. As well, a schedule and plan to review and approve the capital program and operational data should be formulated.

60. Consideration should be given to the expansion of CAAM beyond the initial Project Genesis requirement to address capital costing issues related to Fighter Force capability. CAAM could be extended to cover the entire Air Force capital program. Efforts should be made to ensure that CFD staff fully appreciate the significance of the CAAM methodology as its potential application to the entire DSP.

61. The requirement to directly address input uncertainty within CAAM should be assessed. If it is agreed that uncertainty is a factor that must be explicitly addressed within CAAM, a recommendation to actively pursue the incorporation of @Risk within CAAM should be proposed. Uncertainty in input data values can be captured by representing the data values as three point estimates[4]. Capturing the data in this form should present no additional burden to the planners tasked to supply the input data, and in fact may ease the effort required.

4. A three point estimate for a data element consists of an estimate of the lowest reasonable value, the most likely value, and the highest reasonable value for the parameter.

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SECURITY CLASSIFICATION OF FORM
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DOCUMENT CONTROL DATA
(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared e.g. Establishment Sponsoring a contractor's report, or tasking agency, are entered in Section 8).

OPERATIONAL RESEARCH & ANALYSIS
DIRECTORATE OF AIR OPERATIONAL RESEARCH
NATIONAL DEFENCE HEADQUARTERS
OTTAWA, CANADA K1A 0K2

2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

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3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title)

CAPITAL ASSET AMORTIZATION MODEL (CAAM)

4. AUTHORS (last name, first name, middle initial)

FUNK, R.W.(AIR COMMAND HEADQUARTERS) AND G.L. CHRISTOPHER (DIRECTORATE OF AIR OPERATIONAL RESEARCH)

5. DATE OF PUBLICATION (month Year of Publication of document)

SEPTEMBER 1995

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

40

6b. NO. OF REFS (total cited in document)

10

7. DESCRIPTIVE NOTES (the category of document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

ORA PROJECT REPORT 9510

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address).

AIR COMMAND HEADQUARTERS, PROJECT GENESIS

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

PROJECT 23222-3, PROJECT GENESIS

9b. CONTRACT NO. (if appropriate, the applicable number under which the documents was written.)

10a. ORIGINATOR's document number (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

ORA PROJECT REPORT 9510

10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

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During the inception of Project Genesis, an initiative to streamline Air Force fighter operations and reduce the cost for the provision of a fighter capability, it was discovered that there did not exist a model to account for the total cost of this Air Force component. Models to account for the recurring expenses of personnel, operations and maintenance are available. However, there are no similar models to account for the capital cost associated with a capability. Life cycle costing models do exist, but they do not dynamically account for the effect of operational parameters on the overall annual capital cost of an Air Force capability.

Operational Research was approached to devise a model which could determine the total amortized cost associated with fighter capability. The model must be able to account for all direct and indirect capital expenditures which support the provision of a Canadian Air Force fighter capability. The model must also be able to reflect the effect of changes to operational procedures on the total capital cost of this capability.

The Capital Asset Amortization Model (CAAM) was developed to satisfy this requirement. The model spreadsheet which accepts as input the costs of all capital projects which support the retention of an effective fighter capability. From operational data, CAAM determines the approximate lifetime of the air fleet. For capital projects related specifically to the fighter fleet, the fleet lifetime is used to determine the appropriate amortization period for the projects. For non-airframe-specific projects, an associated technological lifetime is used for amortization calculations.

CAAM provides a summary which identifies the total annual capital cost to provide a fighter capability based on the latest estimates of fleet lifetime. CAAM can be used to establish a baseline cost for fighter capability and measure the effect of changes to infrastructure and operations.

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